BIOLOGY

Science and Life

Michael R. Cummings

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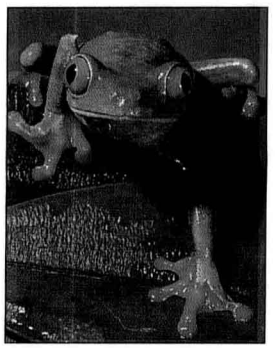

ABOUT THE COVER

In the nineteenth century, coal miners took caged canaries with them into the mines. While they worked, the miners paid close attention to the canaries, which are sensitive to low concentrations of methane and other dangerous gases that accumulate in mines. If the canaries became unconscious, the miners left the mine before they too were overcome.

In the last decades of the twentieth century, there has been a worldwide decline in the number of amphibians, particularly frogs, toads, and salamanders. At various times in their life cycle, frogs live in water and on land, are herbivores, and then carnivores. As a result, they are in intimate contact with many parts of their ecosystem. Several factors are contributing to the accelerated extinction of frog species. These include depletion of the ozone layer and the associated increase in ultraviolet light reaching the earth, habitat destruction, air pollution in the form of acid rain, and pollution of water by herbicides and industrial chemicals.

The sensitivity of frogs to environmental degradation may make them the modern day equivalent of the miner's canary. Amphibians were able to survive the environmental changes that led to the extinction of the dinosaurs, but have not been able to adjust to the effects of human activity on the physical environment. Just as the canary did, perhaps frogs are warning us of danger to our own species.

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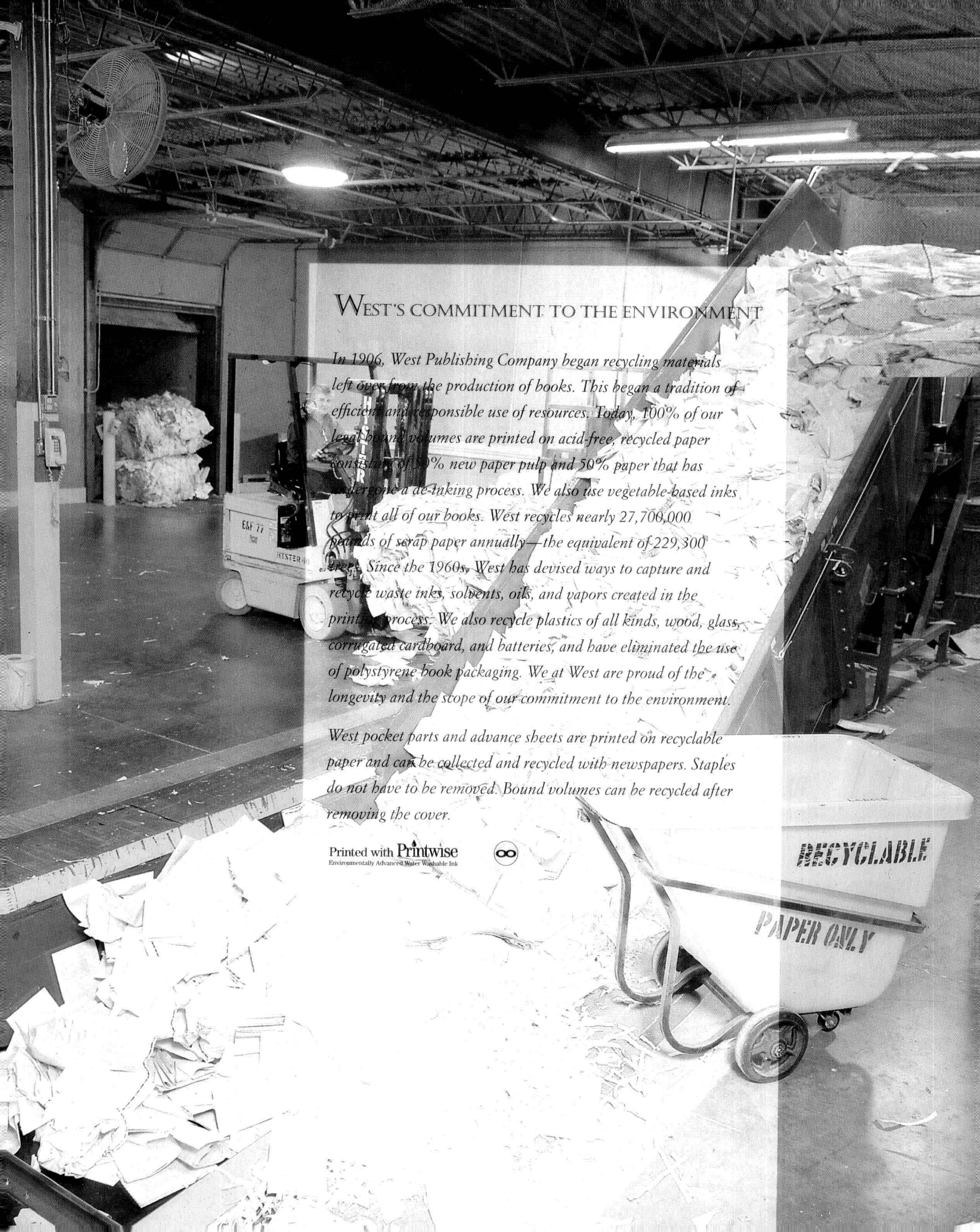

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TO THOSE WHO MEAN THE MOST,

LEE ANN, BRENDAN AND SHELLY,

KERRY AND TERRY, AND COLIN.

PREFACE

During the last few decades, biology has become the fastest growing area of science. Building on advances made in physics and chemistry early in this century, research in biology has generated massive amounts of information and created whole new areas of investigation, ranging from molecular genetics to biogeochemical cycles. In the process, biology has not only grown, but has essentially changed during the last fifty years from a science that describes and catalogs the natural world to one that provides a detailed explanation of the mechanics of the natural world. Even at the present level of understanding, biology is rapidly becoming a predictive science.

This transformation has altered the ways in which biology is studied and how it is taught. New findings are being generated at a rate that threatens to overwhelm those involved in teaching and research. For the student of biology, especially the nonmajor, the conceptual framework can easily be obscured by the overwhelming level of details.

The Rationale for This Book

Mindful of the changes that have swept over biology, this text is written for a one-term introductory biology course for the nonmajor. Unlike other texts, it is not an abridged or diluted version of a textbook originally designed for majors. It has been written by an author who works with undergraduates on a daily basis, teaching basic courses in a biology curriculum to both majors and nonmajors.

In recognition of the need for nonscience students to acquire knowledge of basic biological concepts, rather than an array of facts, each chapter is organized around one or two central ideas. For example, the organizing concept in Chapter 5 is the cell cycle. Once the cell cycle has been explained, the process of mitosis, meiosis, cancer, and aging are interpreted in light of this concept. Without question, new discoveries will continue to refine the concept of the cell cycle and the related processes. If students have a firm grounding in the cell cycle, they will be equipped with a way of thinking about and interpreting newly discovered details, and be able to integrate them into a conceptual framework.

The speed at which technology is being developed from scientific knowledge and the pressure of human population growth make it clear that difficult, informed decisions need to be made at all levels, from the personal to the global. A great many of these decisions, ranging from genetic screening to global warming, will require knowledge of biological principles. Elected leaders and citizens outside the community of biologists need to have a working knowledge of biology in order to shape and support the decisions regarding biological developments that will need to be made in the coming decades. A course and a text based on a hierarchical approach, which links a basic set of biological concepts, can provide the basis for transmitting these principles without unnecessary detail or jargon.

This text has been written with several premises in mind:

1. The use of a limited number of clearly presented, interlinked concepts is the best approach to learning a complex, detailed subject such as biology.
2. A text for nonmajors should be written in a straightforward, clear fashion with relevant examples that students can apply to themselves.
3. The figures and photographs should teach rather than merely illustrate the ideas under discussion.
4. The concepts must be linked by a small number of basic, organizing themes.

The Interwoven Themes

Areas of biology that were once islands of knowledge are rapidly being integrated into a larger picture. As this process continues, a small number of organizing ideas are proving useful in interpreting biological processes. Two of the most powerful of these themes are genetics and evolution. During the last four decades, genetics has illuminated with great clarity the physical and mechanistic bases for the key characteristics of living organisms: how they reproduce, develop, and function.

Evolution is the result of natural selection of genetic variation. All organisms have an evolutionary history that can be extended backward in time to the origin of life on Earth. As forms diverged under natural selection, they carried genetic evidence of their relationship. The recent discovery that the gene controlling eye formation is an ancient genetic

innovation links all organisms with eyes to a common ancestor.

The themes of genetics and evolution are used throughout the texts to organize and link the concepts presented in each chapter. In each chapter, the concepts are presented in an evolutionary context. For example, excretion in multicellular organisms is associated with a tubular structure lined with epithelial cells. This basic unit functionally links the flame cells of the rotifer with the human kidney. A discussion of the genetics of kidney disorders provides an insight into the nature and function of genes involved in excretion.

The Organization

The text is divided into seven parts. Part 1 presents background to understanding the origin, organization, and basic functions of all organisms. The chemical and biological bases of life and the basic properties of all living systems including structure of cells, energy transfer, and cellular reproduction are discussed.

Part II deals with the basic principles of genetics, from Mendelian patterns of inheritance and gene action to applications of genetic engineering. These principles are related to organisms ranging from bacteria to humans to everyday events such as having your cat vaccinated and buying milk.

In Part III, the development of the theory of evolution is discussed and then related to the origin of species, and the events above the species level, emphasizing the relationship between the physical environment and adaptations that allow fitter individuals to survive and leave more offspring.

Many biology texts, especially those for nonmajors, give only cursory treatment to the biology of plants. The emphasis of Part IV is on terrestrial plants and how they developed different adaptations to the same environmental challenges as animals, namely, seasonal variation, protection, desiccation, and gravity.

Part V deals with control systems in animals, briefly describing the evolutionary history of adaptations for establishing and maintaining homeostasis, with a focus on the structure and function of body systems in humans. This serves two purposes: It provides students with an evolutionary perspective and motivates them to learn about concepts to which they can personally relate.

In Part VI, the chapters cover reproduction in plants and animals to contrast again how plants and animals have solved some basic reproductive problems: fertilization in the absence of water, protection of the developing embryo, and the developmental strategies employed in producing the structures of the adult organism.

Part VII deals with organisms and their interactions with the physical environment. This section begins with a description of the structure and life cycle of populations, and how populations form communities. It stresses the important point that natural communities enhance and reinforce the lives of the species that make up the community, and that disruption of any species or of the physical environment can have devastating consequences on the community. The last chapter emphasizes the fact that human populations have grown to the point where the limited resources of the planet are being stressed, and that we need to plan now to manage our physical and biological environment in order to sustain human society.

Although the text is organized in a format that begins with the chemical level and ends with cycles and the biosphere, the text can be used in a variety of formats, including those that place ecology and the environment first. Most chapters have been written to stand alone, so that the parts and chapters can be used in an interchangeable format, providing the instructor with maximum flexibility.

The Pedagogy

Each chapter opens with a short vignette that relates to the concept or concepts to be discussed in the chapter. These episodes have been selected to relate the concepts discussed in the chapter to a real situation, either historical or contemporary, and to kindle student interest in the material to be covered.

As described earlier, each chapter is centered around a limited number of concepts, woven together with a discussion of their evolutionary and genetic aspects. The connections to other concepts and applications of the concepts are also outlined.

Within the chapter, headings are written as descriptive, summary statements that preview the material and often summarize the point of the section. This provides the student with an overview and a convenient way of reviewing the material in the chapter.

The chapters end with a summary that restates the major ideas covered in the chapters. Beginning each chapter with an example of the concept and then ending with a restatement of the concepts and their applications will help focus the students' attention on the conceptual framework and minimize the chance that they will attempt to learn by rote memorization of facts.

At the end of each chapter, questions test the students' knowledge of the facts and their ability to reason from the facts to conclusions. Some questions relate biology to our society and our culture.

Several elements of the text are designed to serve as a built-in study guide for the student. Chapter 1 provides an overview of biology and the organization of the book. This chapter is followed by a section on developing study skills. It has been positioned here to make it visible, to provide a list of study skills and how to acquire them, and to assist the student in preparing for examinations. This is followed by the opening vignette of Chapter 2 as a lead-in to the material on the chemistry and origin of life. All chapters use opening vignettes to set the stage for the topics to be discussed. Other elements in chapters serve as part of a built-in study guide. These include the use of statements as primary and secondary headings, chapter summaries in list form, a list of key terms in the chapter, all of which are defined in the text and in the glossary, and the end-of-chapter questions that test recall of facts and applications of the chapter's concepts to social issues.

Throughout the book, sidebars are used to highlight applications of concepts, discuss oddities of nature, present controversial ideas, and communicate the latest results in a field, without interrupting the flow of the text.

The Art Program

The art program is based on more than 25 years of classroom experience teaching undergraduates. To be effective, classroom illustrations must condense concepts and communicate major points effectively. This experience has been reinforced by more than a decade of preparing illustrations for textbooks of genetics, a field that underpins and informs much of modern biology. For this text, the result is uncluttered and effective illustrations that parallel the presentation of material in the text. To emphasize the parallel importance of text and art as pedagogical devices, the text and its relevant illustrations are presented on the same page or same two-page spread. Students will not have to turn pages to find figures or photos that relate to the point being discussed. In addition, colored icons in the text highlight the figure callouts, allowing the student to return quickly to the appropriate place in the text after studying the figure.

Like the text, the art program is concept driven, and the resulting illustrations are clear summaries of a concept under discussion, without unnecessary text, labels, or detail. This is accomplished by having the illustrations supported by a detailed explanation of the concept in the text, allowing the art to be an unencumbered summary, often in the form of a flow diagram of a process or concept.

The Human Connection

The book covers many aspects of biology, and presents examples from organisms ranging from prokaryotes to primates. Because it is easiest for students to relate biological concepts to their own lives, several features of the text have been constructed to connect the concepts and the process of science to the everyday experience of the students. Some of these features are as follows:

1. **Science and Society.** At the end of each chapter, one or more open-ended questions ask the students to apply what they have learned to common situations. These questions are wide ranging, and include considering how the diet of spiders might be beneficial to humans, whether it is ethical to use zoos to preserve endangered species of primates, or how to balance the risks of using radioactive isotopes with diagnosis and treatment of disease.
2. **Beyond the Basics.** Boxed material in each chapter relates concepts in the chapter to topics that either elaborate ideas presented in the chapter or are interesting, but tangential, examples that should be of interest to the students. These include heat-generating plants, speculation that early hominids used tools as killer frisbees, and the use of insects found on corpses to establish the time of death.
3. **Guest Essays.** To emphasize that science is a human endeavor, and is always in the process of refinement, the book contains essays written by scientists, describing how they became interested in science, what they study, and how their research relates to the larger context of human society. These essays are not just about the scientists, but are written *by* the scientists, providing students with insights into the lives, thoughts, and motives of biologists.

The text and coordinated ancillaries also incorporate other features, which are described in the following section.

ANCILLARIES

To assist you in teaching this course and supplying your students with the best in teaching aids, West Publishing Company has prepared a complete supplemental package available to all adopters.

For the Instructor

The comprehensive instructor's manual and test bank, prepared by Judith Lanum Mohan of Case Western University, includes teaching ideas, chapter

overviews, learning objectives, discussions of common student misconceptions, audiovisual and multimedia sources, Internet sources, and the test bank containing approximately 3000 multiple choice, true/false, fill-in-the-blank, matching, short answer, analogy, and quantitative questions.

The entire test bank is provided on diskette along with WESTEST, a computerized testing package. Using WESTEST 3.1, instructors can generate examinations containing questions they select or have questions randomly generated by the computer. Instructors can also use the WESTEST 3.1 edit function to modify theses questions, add new questions, or delete existing questions. Additionally, West's Classroom Management software allows student data to be recorded, stored, and used for various reports.

West provides an on-line update service through its HomePage containing articles by the text author. Dr. Cummings reports monthly on new and interesting developments in the field of biology since the publication of the text, West's Instructor's Reference CD-ROM, which contains all of the instructors' printed supplements, WESTEST 3.1, the Classroom Management Software, the electronic presentation package, and all of the art from the text, provides instructors with a single source for the supplements.

A slide set and full-color transparency acetate set provide clear, effective illustrations of 150 of the most important artwork and maps from the text.

An electronic slide presentation package using Persuasion, prepared by Michael Farabee of Estrella Mountain Community College, provides text outlines, guiding questions, all artwork, with 3–4 available as animations, and photos for each chapter of *Biology: Science and life.* The presentations are available for Macintosh and for Windows. Instructors with Persuasion software can customize the outlines, art, and order of presentation. The text's art has been converted to a visual format suitable for computer projection in the classroom.

West also has available its Biology Videodisc which includes animations of intricate processes, illustrations, and video footage. Used in conjunction with Lecture Builder software you can create, edit, store and build upon your own personalized lectures.

Understanding Human Evolution software, by Ronald Wetherington, contains 13 interactive evolution exercises with graphics. For example, in one interactive simulation, students compare dominant/recessive selection and balanced polymorphisms. It's available for IBM PCs or compatibles with at least 256k.

Other multimedia is available to qualified adopters. Please contact the local West sales representative for more details.

For the Student

Current Perspectives in Biology, edited by Shelly Cummings of the University of Chicago, is a collection of approximately 50 very current articles chosen from general interest and science magazines to supplement material that students will encounter in their course work. West can make this supplement available with the text as a set, or it can purchased separately.

Laboratory Manual for Introductory Biology, Second Edition by Jay M. Templin is a concise, easy to follow laboratory manual that covers all of the major themes of contemporary biology. The labs emphasize the discovery process by challenging students to predict what will happen or explain what has happened during an experiment. The second edition provides a more even balance of animal and plant exercises. In addition, human fluids are no longer used in any experiment. When needed, artificial fluids are substituted. The lab manual includes full color photos of pig dissections. An Instructor's Manual is also available.

A study guide, written by Richard Friedman Drexel University, is closely tied to the main text. The guide provides students with an overview of each chapter, learning objectives, exercises to test the students on key terms, chapter concept questions, experiments and activities, diagram labeling exercises, and practice exams consisting of multiple-choice, true/false, fill-in-the-blank, and matching questions.

Internet Activity Booklet, tied to the West Publishing home page for address updates, provides projects for students to get the latest information and data on topics such as recent research in genetics.

Exploring Critical Issues in Biology by Andrea Huvard (California Lutheran University) contains 34 biological topics and issues (genetic engineering, AIDS, evolution and human intelligence) presented to encourage students to understand practical applications of their studies in biology. Questions at the end of each discussion provide a springboard for critical analysis.

Study Skills for Science Students by Daniel Chiras is an 86-page booklet which offers practical tips on notetaking, test-taking, reading efficiency, concept mapping, and using computer software tutorials.

A Student Note Taking Guide contains printed copies of all of the art that is used in the electronic slide presentation package. Bound with perforated, 3-hole punched pages, it allows students to take notes as the slides are shown in lecture. The complete text of Study Skills for science students is also included.

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A book of this type represents a major undertaking for both the author and the publisher. At West Publishing, there are a myriad of people to thank for their vision, energy, and dedication to this book. Rex Jeschke, manager of the College and School Division, helped put the full resources of the publisher behind this project. I am grateful to him for his efforts and for his work with the American Publishers Association on behalf of all textbook authors. My editor, Jerry Westby, is a man of great patience and forbearance. This book had a long gestation period, and throughout, his enthusiasm and encouragement never flagged. His creative contributions, ability to look at things from the side of the student, and commitment to undergraduate education helped to shape the text and many of its features. As before, his friendship and advice have been among the most valuable benefits of this project. Dean DeChambeau, the developmental editor, was, as usual, unflappable in the face of crises. His work provided a clear overview of the strengths and weaknesses of the manuscript. Dean was also instrumental in developing much of the ancillary material that expertly serves the needs of both students and instructors. Special thanks to Halee Dinsey, the developmental editor who worked closely with Michael Farabee of Estrella Mountain Community College to develop the state-of-the-art electronic lecture presentation software and Internet activities supplement described earlier. Betsy Friedman was a miracle worker in assembling the list of guest essayists, and nudging them when necessary to get the essays in on time. She made it look easy, even though it was, I am sure, an often frustrating task. The copyeditor, Loretta Palagi, worked diligently to keep my grammar and punctuation within the limits of acceptable use.

The transformation of a manuscript into a book requires the efforts and strong support of a production staff. In this case, I stood by in awe as the production team poured their creative energies and time into this book. The production editors, Sandy Gangelhoff and Matt Thurber, believed in this project and were relentless in their insistence on excellence in all aspects of manuscript preparation, the art program, and the photo program. The design of the book, the cover, and page layout were created by Diane Beasley. Their enthusiasm, persistent efforts and attention to the smallest detail are responsible for the remarkable book you are now reading. I am grateful to have had the opportunity to work with these talented individuals.

Ann Hillstrom and Ellen Stanton spearheaded the development of the marketing program that brings the innovations, pedagogy, and themes of this book to the attention of potential adopters.

I would also like to thank my colleagues who contributed to this book. Judy Verbeke provided valuable insight into undergraduate teaching and did the first drafts of Chapters: 16, 17, and 27. Mike McKinney lent his expertise in reviewing most of the chapters in Part II, and prepared the first drafts of Chapters 30, 31, and 32. Their efforts have greatly enhanced the book. Special thanks are due to Shelly Cummings, who wrote the Questions and Problems and the Science and Society questions at the end of each chapter. She also researched and wrote the sidebars for all of the chapters. In the face of tight schedules and looming deadlines it was always reassuring to know that her optimism and diligence would carry the day. Patricia Lewis took on the daunting task of preparing the glossary, an important study aid for students struggling with the vocabulary of biology.

This book went through a number of meticulous reviews for both content and style. The comments and suggestions of the following reviewers has enhanced the focus and presentation of the material.

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LEARNING GUIDE

Before you become absorbed in this textbook, take a moment to look over the next few pages. We've provided an overview of the built-in learning devices you'll find throughout the book. Becoming familiar with these unique features can make it easier to navigate through the material.

GETTING STARTED

Chapter outlines will get you started with a quick overview of what topics you can expect to cover.

Prologues open each chapter. These engaging short stories provide a fascinating glimpse into a number of diverse subjects. Interested in the big bang theory? Turn to the prologue to Chapter 2. Ever wonder what your body has in common with a car? Check out the prologue to Chapter 4. All of the prologues were written to make your journey into biology as interesting and rewarding as possible.

C H A P T E R

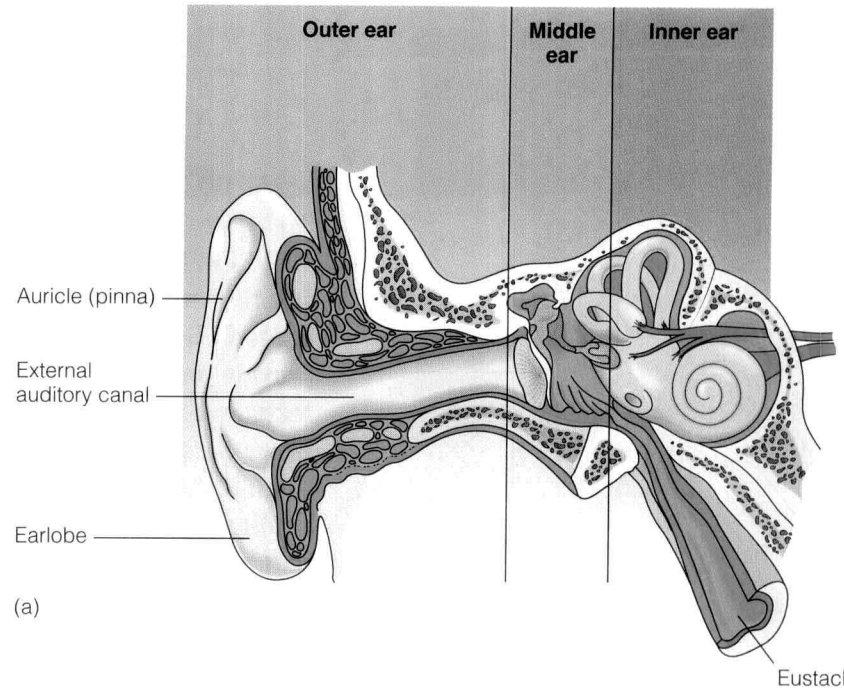
O U T L I N E

At the Marine Biological Laboratories at Woods Hole, Massachusetts, scientists gather each summer as they have for more than 100 years to teach, to learn, and to conduct experiments using the marine plants and animals that can be collected there. In the summer of 1982, a group of young scientists led by Tim Hunt began experiments designed to study biochemical changes that take place after fertilization of the sea urchin egg. They decided to examine new gene products (gene products are proteins) made in the hours immediately after fertilization, a time when a series of cell divisions take place. They fertilized a batch of sea urchin eggs and, at 10-minute intervals, analyzed the newly made proteins during the first 2 to 3 hours of development. The fertilized egg first divides at about 60 minutes, and again about 2 hours after fertilization, resulting in a four-cell embryo.

Several new proteins appeared almost immediately after fertilization, including one that exhibited unusual behavior. This protein was continuously synthesized, but was unexpectedly destroyed just before each round of cell division. Because of its cyclic behavior, this protein was called **cyclin.** *Experiments using another species of sea urchin revealed two cyclins that periodically disappear during the cell divisions associated with early development. Investigating other organisms available at Woods Hole, this group discovered that the developing eggs of clams also contain cyclins. Because these proteins disappear... (continued)*

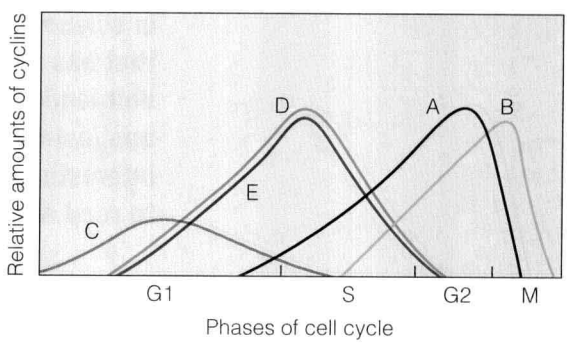
BEAUTIFUL AND INSTRUCTIONAL COLOR

As you look through the text, you'll notice the consistent use of vibrant colors. Not only are the colors beautiful to look at, but they also make for clearer and more informative illustrations.



EVERYTHING IS RIGHT WHERE YOU NEED IT

If you've ever found yourself flipping back and forth between pages, trying to find the illustration that the text refers to, you'll appreciate the effort that went into the page layout of this book. Whenever possible, illustrations and photographs appear on the same page or spread as the text they accompany. This makes it much easier to go back and forth from text to visuals.



✦ **FIGURE 5.13**

Different cyclins (A–E) are produced and destroyed at different times in the cell cycle. Each cyclin plays a role in regulating passage of a cell through the cell cycle.

NOW, WHERE WAS I?

You just spent a few minutes studying an illustration and now you can't remember where you left off reading. This little red diamond appears next to figure references within the text. It's a little feature, but a real time-saver.

The signals that are part of this switch point in the cell cycle were discovered as a result of the work started at Woods Hole in 1982. These signals are generated by the synthesis and action of cyclins (✦ Figure 5.13). At the G1 control point, a cyclin combines with another protein, generating a signal that moves the cell from G1 into S. What signals cause the production and destruction of cyclins are not yet known.

Cancer cells have disabled this and other control points, and divide continuously. Mutations in genes that control the synthesis or action of cyclins are important in generating the transformation of a normal cell into a cancer cell.

Sidebar

CELL DIVISION AND SPINAL CORD INJURIES

Many highly differentiated cells, like those of the nervous system, do not divide. They are sidetracked from the cell cycle into an inactive state called G0. As a result, injuries to nervous tissue such as the spinal cord cause permanent loss of cell function and paralysis. For years, scientists have worked to learn how to stimulate growth of spinal cord cells so that injuries can be repaired. Recent work suggests that it may soon be possible to get nerves in the spinal cord to reconnect to their proper targets and to restore function in nerve cells that are damaged, but not cut. Researchers have shown that the severed spinal cords of young rats can be reconstructed by transplantation of the corresponding section of spinal cord from rat embryos. When the rats reached adulthood, most of the sensory and movement was restored.

Other researchers have isolated a growth factor found only in the central nervous system that causes cell growth from the ends of severed spinal cords. Whether such growth can result in reconnection of nerves to their proper muscle targets, and whether function can be restored are unresolved questions.

WHAT DO DEEP SEA VENTS HAVE TO DO WITH CONVICTING A SUSPECTED MURDERER?

The *Sidebar* in Chapter 4 explains how bacteria living in 100°C water at the vents provide proteins used in recombinant DNA techniques such as DNA fingerprinting. Other *Sidebars* throughout the text provide brief descriptions of human health applications, new discoveries, and quirks of nature–and, at the very least, they're great for impressing friends and family.

GUEST ESSAYS

Here's your chance to read what scientists have to say about the roots of their interest in science, their careers, and basic research that has resulted in important, but often unintended, discoveries with beneficial applications. *Guest Essays* are fun and interesting to read—you might be tempted to read all of them first.

WHEN YOU JUST HAVE TO KNOW MORE

If we included in-depth coverage of every interesting topic in biology, this text would be very difficult to finish in one term, much less to carry. But some topics are *so* compelling, that you want to know more. *Beyond the Basics* boxes feature topics of special interest and develop them a little further and in more detail.

GUEST ESSAY: RESEARCH AND APPLICATIONS

A Life of Questions: The Questions of Life

NANCY KEDERSHA

Most children go through a "What?" stage, progress on through "Why?" and "How?" and eventually grow into adults concerned with increasingly specific questions, such as "Will you marry me?" and "How much does this cost?" I never gave up asking the "What? How?" questions, and they have led me into science. How do seeds grow into plants? How do robins find worms? How do living things grow and move? These questions that I asked as a child are still meaningful to me as an adult. Living things are both so beautiful and so interesting that I could never decide whether I preferred to pursue art or science full time.

My college years were spent shuttling between the biology labs and the university theater, so I was usually either looking through a microscope at diatoms I had cultured or focusing lights on scenery I had built and painted. After college, I was still reluctant to commit myself exclusively to science. I deferred graduate school and I took a job as a lab technician in a biomedical research lab. Working on cells "hands on" I gradually came to realize that being a scientist was much more of an art than I had realized. Glassblowing, photography, assembling posters, and redesigning equipment were as much a part of my job as growing cells or purifying proteins. The lab was a place where skill and "good hands" were needed as well as knowledge, and where someone who asked a lot of questions was just doing her job proficiently rather than being a pain in the neck.

In science, as in life, my curiosity has led me to a series of serendipitous discoveries. In graduate school, I saved one of the "contaminant" proteins I was purifying away from my main "thesis-related" protein, and found that the contaminant was a new form of the well-known protein actin, differing in its location within cells as well as its biochemistry. While learning to use the electron microscope, I found some strange and beautiful structures in the "garbage" fractions that normally would have gone down the drain. For months afterwards, any hapless scientist visiting the lab was handed photographs of these structures and ruthlessly grilled: "Have you ever seen anything like THESE before??" No electron microscopist for miles (we asked a lot of them!) could identify these particles. We named them "vaults" because of their beautiful and intricate morphology, reminiscent of the multiple arches that form vaulted cathedral ceilings.

One question that people ask me is "If there are so many of these in all cells, why didn't anyone ever see them before you?" One answer is that vaults can't be seen in samples prepared for electron microscopy using normal stains, and are in essence invisible in conventionally prepared sections of cells. The technique I was using enabled me to see them, and another new technique allowed me to purify them. Vaults were in fact actually photographed and appeared in publications as contaminants of coated vesicle preparations. No one realized they were intact new structures instead of fragments of coated vesicles until I purified them. So perhaps the most complete reason why no one ever saw them was because nobody looked using the right tools, and when they did use the right tools, they didn't ask the right questions. The "right" question I asked was "What are these things?" And now that we know more about what they are, the question is "What do they do?"

Powerful new techniques, instrumentation, and computers have resulted in an explosion of data that is coming in faster than we can digest or integrate. Science is a process to make sense out of data and understand the principles behind events. Like a microscope or a telescope, science is also a way of viewing the world, and it evolves like a living organism as does our understanding. The more I look, the more I see; the more questions I answer, the more new ones I perceive. I find such beauty in the answers that for me, art and science are one.

Nancy Kedersha is a research scientist at Immunogen, Inc., in Cambridge, Massachusetts. She has published dozens of articles on topics in cell biology, and her photos of cancer cells have won numerous prestigious international awards. Her work has been the subject of feature articles in several national and international magazines.

Beyond the Basics

GENES, CELL DIVISION, AND CANCER

Cancer is a disorder of cellular reproduction. This condition arises from within the cell, causing cell division to be out of control; cells continually move through the cell cycle and divide, giving rise to daughter cells that also undergo continuous division. Cells may also break away from the original tumor mass and establish new tumor sites elsewhere in the body (a process known as **metastasis**). Because the ability to divide in an uncontrolled fashion is passed on to the progeny of cancer cells, it is logical to assume that this property is under genetic control. The question is, if genes are involved in cancer, which ones are they and what do we know about them?

Until recently, these questions were difficult if not impossible to answer. Now however, scientists are uncovering two types of genes that are associated with the development of cancer, **tumor suppressor genes** and **oncogenes.** The first group contains genes that normally keep cell division in check, preventing the cell from responding to external and internal commands to divide. If one or more of these genes are damaged or absent, restraints on cell division are removed, leading to the formation of tumors.

The second group of genes, the oncogenes, are able to activate cell division in cells that normally do not divide or do so only slowly. In other words, when these genes are damaged, or make gene products at inappropriate times or in the wrong amounts, resting cells begin to divide in an uncontrolled fashion, causing tumor formation.

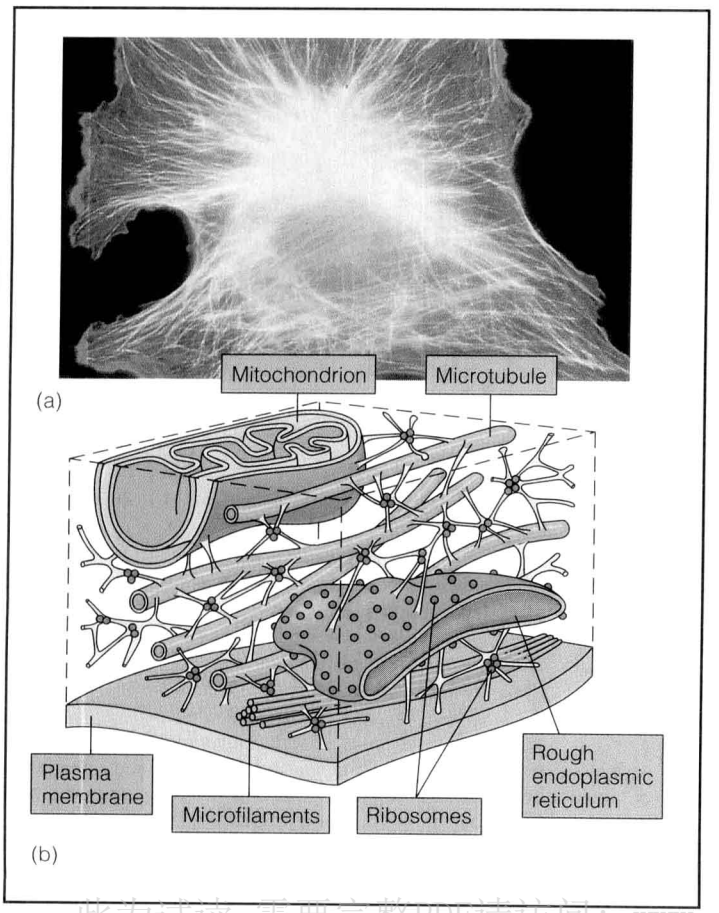
At the present time, fewer than 10 tumor suppressor genes have been discovered, but more than 75 oncogenes have been described. The importance of oncogenes in relation to cancer can be shown by the fact that scientists working with oncogenes were awarded Nobel Prizes for their efforts in 1966 and 1989. New research on cancer genes is aimed not only at discovering more of these genes, but at understanding how the action of these genes at the molecular level fits into the network of external and internal signals that bombard the cell and result in a decision to move through the cell cycle and divide.

Some Cells Divide by Binary Fission

In the cells of prokaryotic organisms, including blue-green algae and other bacteria, cell division follows a period of growth during which the cell enlarges by synthesizing new sections of the cell wall and by making more cytoplasm. During this period of growth, the circular DNA molecule that serves as a chromosome is copied. Each copy of the chromo
ner surface of
sides of the cel
gates by the ac
the attachmen
move further a
the cell wall an
ward. Eventua

Meiosis I Reduces the Chromosome Number

In the first stage of prophase I, the chromosomes coil, thicken, and become visible under the microscope. As the chromosomes condense, the nucleoli and nuclear membrane disappear and the spindle becomes organized. Each chromosome physically associates with its homologue, and the two chromosomes line up side-by-side, a process known as **synapsis** (Figure 5.15). During synapsis, each chromosome is composed of two sister chromatids held together at the centromere, and the four chromatids in the cluster are often referred to as a **tetrad.** During this stage, evidence for a physical exchange of chromosome material between homologous... (continued)



SUBSECTION HEADINGS ARE FULL SENTENCES

Instead of traditional topic titles for each subsection (for example, Cell Division or Meiosis I), full statements like the ones shown at the left foreshadow the main points to come. It may not seem like a big deal, but it can really improve your comprehension.

BUILT-IN STUDY AIDS

Need a quick memory refresher for an upcoming exam? Chapter summaries reinforce the main topics covered in each chapter.

Cytokinesis? Diploid? Gametes? Important key terms are listed at the end of each chapter. For complete definitions just flip to the glossary in the back of the book. It's easy to find—there's a colored band on the edge of each glossary page so you can open right to it.

***Questions and Problems* at the end of each chapter are another great way to test your knowledge of the subject matter.**

Brief objective questions (with answers in the back of the book) along with the *Developing Your Abilities To Think and Study* section between Chapters 1 and 2, provide all the basics for a short-form study guide. *Science and Society* questions require the use of analytical skills to discuss scientific and societal issues with which we may be confronted in coming years.

THE WHOLE PICTURE

In many cases photographs and illustrations are used together (as in the example to the left) to visually explain concepts.